STUDY OF TENSILE AND FLEXURAL PROPERTIES OF LUFFA FIBER REINFORCED EPOXY COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering

By

JAGANNATHA SAHU (109ME0414)

Under the Guidance of

Prof. S.K.Acharya

Department of Mechanical Engineering
National Institute of Technology
Rourkela

(2013)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008

CERTIFICATE

This is to certify that the thesis entitled, "**STUDY OF TENSILE AND FLEXURAL PROPERTIES OF LUFFA FIBER REINFORCED EPOXY COMPOSITE**" submitted by Sri JAGANNATHA SAHU (109ME0414) in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at the NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter personified in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

Prof. S. K. Acharya
Dept. of Mechanical Engineering
National Institute Of Technology
Rourkela-769008

ACKNOWLEDGEMENT

It gives me immense pleasure to express my sincere gratitude to my supervisor, Dr. S.K.Acharya, Professor, Department of Mechanical Engineering, NIT, Rourkela for suggesting the topic for my thesis report and for his ready and able guidance throughout the course of my preparing the report. I am greatly obliged to him for his constructive suggestions and criticism from time to time during the course of progress of my work.

I would like to express my deep sense of gratitude to Mrs. Niharika Mohanta, Phd. Scholar, Department of Mechanical Engineering, NIT, Rourkela for her invaluable guidance and support during the course of this project work. She has been a constant source of inspiration and her ever-cooperating attitude empowered me in working all the initial surveys, experiments and also to expel this thesis in the present form.

I am extremely thankful to Prof. K.P. Maity, Head of the Department of Mechanical Engineering, NIT, Rourkela for providing all kind of necessary facilities in the department to carry out the experiment.

I also express my heartfelt thanks to Prof. S. K. Pratihar, Dept. of Ceramic Engineering course for his timely help during the course of work. And at last I am extremely thankful to all my friends, well-wishers and classmates for their motivation and inspiration during this project work.

Date:

JAGANNATHA SAHU

(109ME0414)

CONTENTS

ABSTRACT

In current years composites have concerned considerable importance as a potential operational material. Low cost, light weights, high specific modulus, renewability and biodegradability are the most basic & common attractive features of composites that make them useful for industrial applications. With low cost, high specific mechanical properties natural fiber signifies a worthy renewable and biodegradable substitute to the most common synthetic reinforcement i.e. glass fiber. There are numerous potential natural resources in India. Most grows from the forest and agriculture. Luffa- cylindrica locally called as "sponge-gourd" is one such natural resource whose potential as fiber reinforcement in polymer composite has not been explored till date for tribological applications. Against this back ground the present research work has been commenced with an objective to explore the use of natural fiber Luffa as a reinforcement material in epoxy base.

The presented work in this thesis includes study of two different problems of natural fiber composites:

a) A study of favorable mechanical properties of luffa fiber in thermosetting matrix composite.
b) An experimental analysis of mechanical potential of Luffa fiber reinforced composite.

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

1.1 Background

In the current quest for improved performance, which may be specified by Numerous criteria comprising less weight, more strength and lower cost, currently used materials frequently reach the limit of their utility. Thus material researchers, engineers and scientists are always determined to produce either improved traditional materials or completely novel materials. Composites are an example of the second category. Over the last thirty years composite materials, plastics and ceramics have been the prevailing emerging materials. The volume and numbers of applications of composite materials have developed steadily, penetrating and conquering new markets persistently. Modern composite materials establish a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

Composites have already proven their worth as weight-saving materials; the current challenge is to make them cost effective. The hard work to produce economically attractive composite components has resulted in several innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry.

India endowed with an ample availability of natural fiber such as Bamboo, Ramie, Jute, Sisal, Pineapple, Coir, Banana etc. has focused on the improvement of natural fiber composites mainly to explore value-added application avenues. Such natural fiber composites are well matched as wood substitutes in the housing and building sector. The development of natural fiber composites in India is based on two cleft strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers.

The developments in composite material after meeting the challenges of aerospace industry have poured down for catering to domestic and industrial applications. Composites, the spectacle material with light-weight; high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like wood, metals etc. The material experts all over the world focused their attention on natural composites to cut down the cost of raw materials.

1.2 Definition of composites

A composite material is defined as a material system which consists of a mixture or a combination of two or more distinctly differing materials which are insoluble in each other and differ in form or chemical composition. Thus composites are combination of two materials in which one of the materials called reinforcing phase is in the form of fiber sheets or particles and are embedded in other materials called the matrix phase. Composites are made by combining two or more natural or artificial materials to exploit their useful properties and minimize their flaws. Glass-fibers reinforced plastic (GRP), combines glass fibers (which are strong but brittle) with plastic (which is flexible) to make a composite material that is tough but not brittle, is one of the oldest and best-known composites. Composites are typically used in place of metals because they are equally strong but much lighter. Most composites contain fibers of one material tightly bound into another material called a matrix. The matrix binds the fibers together a bit like an adhesive and makes them more resistant to external damage, whereas the fibers make the matrix stiffer and stronger and help it resist cracks and fractures. Fibers and matrix are usually (but not always) made from different types of materials. The fibers are typically carbon, glass, silicon carbide, or asbestos, while the matrix is usually metal, plastic, or a ceramic material (though materials such as concrete may also be used).

1.3 Need of a composite?

Paradigm in Materials Science: “smaller is stronger”. In the present stage of technological improvement, the strongest materials that can be easily handled are manufactured in the form of small diameter fibers (< 200 μm). The use of fibers in structural elements has the following limitations:

- Punching
- Surface damage (wear, abrasion and chemical attack)

- Buckling
- Optimum orientation

These problems are overcome when the fibers are embedded in a continuum matrix. Composite materials were developed in parallel with the manufacturing of new fibers with high stiffness and strength. Thus, the first reason to use composite materials is to take advantage of the outstanding mechanical properties of fibers. The dispersion of reinforcements (either particles or fibers) can improve the matrix properties (toughness of ceramics, conductivity of polymers, high temperature mechanical properties of metals,), leading to new applications.

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of reinforcement material and matrix, a novel material can be made that exactly meets the requirements of a specific application. Composites also give design flexibility because many of them can be molded into complex shapes.

1.4 Constituent Materials

The major constituents of a fiber reinforced composite material are reinforcing fiber, matrix, coupling agents, coatings and fillers. Fibers are the principal load carrying members while the matrix which surrounds it, keeps them in proper location and correct orientation. Matrix acts as the medium by which the load is transferred through the fibers by means of shear stress. Matrix protects the fiber from environmental damages caused by elevated temperature and humidity. Coupling agents and coatings applied to fibers improve their wettings with the matrix and also facilitate bonding across the fiber-matrix interface. The major purpose of using fillers in some polymeric matrices is to reduce cost and achieve a better dimensional stability.

1.4.1 Fibers

Materials in fiber form are stronger and stiffer than that use in bulk form. There is a likely presence of flaws in bulk material which affects its strength while internal flaws are mostly absent in the case of fibers. Further, fibers have strong molecular or crystallographic alignment and are in the shape of very small crystals. Fibers have also a low density which is advantageous.

Fiber is the most important constituent of a fiber reinforced composite material. They also occupy the largest volume fraction of the composite. Reinforcing fibers as such can take up only its tensile load. But when they are used in fiber reinforced composites, the surrounding matrix enables the fiber to contribute to the major part of the tensile, compressive, and flexural or shear strength and stiffness of FRP composites.

1.4.2 Polymeric Matrix

Polymers are divided into two broad categories: thermoplastic and thermoset. Thermoplastic polymers are those which are heat softened, melted and reshaped as many times as desired. But a thermoset polymer cannot be melted or reshaped by the application of heat or pressure.

Depending on the particular thermoplastic material used, thermoplastic matrix components can, however, be used over a wide range of temperature – from 100 C to 300 C. the advantage of thermoplastic matrices are their improved fracture toughness over the thermoset matrix and their potential of much lower cost in the manufacturing of finished composites.

Traditionally, thermoset polymers (also called resins) are extensively used as a matrix material for fiber reinforced composites in structural composite components. Thermoset polymers develop thermal stability and chemical resistance. The main disadvantages are their limited storage life at low temperature, the considerable time wastage using this matrix in fabrication in the mould and low value of strains to failure.

For the purpose of a simple classification, we may classify the thermosets into five groups:

(i) Polyester resin
(ii) Epoxy resin
(iii) Vinyl ester resin
(iv) Phenolic resin
(v) High performance resin

(i) Polyester resin:

The most commonly used resin in glass reinforced plastic construction is the polyester resin and they have exhibited good performance. An unsaturated polyester resin is formed by the reaction of (a) a saturated difunctional acid, (b) an unsaturated difunctional acid, (c) a difunctional glycol. The main advantages of polyester resins are their reasonable cost and ease with which they can be used.

(ii) Epoxy resins

Epoxy resins are mostly used in aerospace structures for high performance applications. It is also used in marine configurations, rarely though, as cheaper varieties of resins other than epoxy are accessible.

Epoxy is a copolymer; that is, it is formed from two distinct chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxide group at either end. Most communal epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, though the latter may be substituted by similar 45 chemicals. The hardener consists of polyamine monomers, for example triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxide groups to produce a covalent bond. Each NH group can react with an epoxide group, so that the resultant polymer is heavily cross linked, and is thus very hard and strong.

(iii) Vinyl ester resins

Being a combination of the principles of both epoxy and polyester resin chemistry, vinyl ester resins have a close resemblance to polyester resins, but have a chemical similarity to epoxy resins. Vinyl ester resin is superior to polyester resin because it offers greater resistance to water. These resins provide superior chemical resistance and superior retention properties of strength and stiffness at elevated temperature.

Vinyl ester resins are between polyester resins and epoxies from the cost point of view.

(iv)Phenolic resins

The main characteristics of phenolic resins are their excellent fire resistance properties. As such, they are now introduced in high temperature application area. The recently developed cold-cure varieties of phenolic resins are used for contact molding of structural laminates.

Phenolic resins have mediocre mechanical properties to both polyester resins and epoxy resins, but have higher maximum operating temperature, much better flame retardant and smoke and toxic gas emission characteristics.

Phenolic resins are increasingly used in internal bulkheads, decks and furnishings in ships.

(iv) High performance resins

Attempts are on for the development of matrices with better properties at elevated temperatures. It has been observed that processing characteristics deteriorate with the increase of thermal stability.

1.4.3 Prepegs

If fiber and matrix were available commercially as one entity, it avoids the procurement of fiber and matrix separately. Partly cured matrix resins act as a binder to well laid out fiber system. These fibers are known as prepegs. They may be unidirectional or woven. Due to its tacky texture it is easy to handle and can best be used in moulding of complex geometrical shapes.

1.4.4 Filler and Other Additives

Filler may be added to the polymeric matrix for one or more of following reasons:

- Reduction of cost
- Increase of modulus
- Control of viscosity
- Production of a smoother surface

The most common filler in polyester and vinyl ester resins is calcium carbonate. It not only reduces the cost but also lessens mould shrinkage. Examples of other fillers are clay, mica, and glass microspheres. Although fillers increase the modulus of an unreinforced matrix, they also tend to reduce its strength and impact resistance.

The impact strength and crash resistance of brittle thermosetting polymers can be improved by mixing them with small amounts of elastic elastomeric toughness.

1.5 Types of composites

1.5.1 On the basis of matrix:

Broadly, composite materials can be categorized into three groups on the basis of matrix material. They are:

1.5.1.1 Metal Matrix Composites (MMCs)

1.5.1.2 Ceramic Matrix Composites (CMCs)

1.5.1.3 Polymer Matrix Composites (PMCs)

1.5.1.1 Metal Matrix Composites (MMCs)

Metal matrix composites, as the name suggests, have a metal matrix. Examples of matrices in such composites comprise aluminum, magnesium and titanium. The typical fiber contains carbon and silicon carbide. Metals are generally reinforced to suit the requirements of design. For example, the strength of metals and elastic stiffness can be increased, while the thermal and electrical conductivities of metals, large co-efficient of thermal expansion can be reduced by the addition of fibers such as silicon carbide.

1.5.1.2 Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as calcium, alumina, alumina silicate reinforced by silicon carbide. The advantages of CMC include its hardness, high strength, chemical inertness, high service temperature limits for ceramics and low density. They are naturally resistant to high temperature. They have a tendency to become brittle and to fracture.

1.5.1.3 Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermosetting or thermoplastic reinforced by fiber (natural boron or carbon). These materials can be molded into a variety of sizes and shapes. They provide abundant stiffness and strength along with resistance to corrosion. The purpose for these being most common is their high strength, low cost and simple manufacturing methods. Due to the lower density of the ingredients the polymer composites often show outstanding specific properties.

1.5.2On the basis of reinforcing materials:

Composites materials are categorized into two groups on the basis of reinforcing materials.

1.5.2.1 Particulate Composites

1.5.2.2 Fibrous Composites

1.5.2.1 Particulate Composites

As the name itself indicates, the reinforcement is of particle nature (platelets are also included in this). It may be cubic, spherical, a platelet, tetragonal, or of other regular or irregular shape, but it is roughly or approximately equated or equal in shape. Thus, particulate-reinforced composites include those reinforced by flakes, rods, spheres and many other shapes of roughly equal axes. In general, particles are not very operative in improving fracture resistance but they improve the stiffness of the composite to a limited extent. Particle fillers are broadly used to improve the properties of matrix materials such as to modify the electrical and thermal conductivities, reduce friction, improve performance at elevated temperatures, increase abrasion and wear resistance, improve machinability, increase surface hardness and reduce shrinkage.

1.5.2.2. Fibrous composite

A fiber is characterized by its length being much larger compared to its cross-sectional dimensions. The dimensions of the reinforcement define its competence of contributing its properties to the composite. Fibers are very effective in refining the fracture resistance of the matrix subsequently a reinforcement having a long dimension depresses the growth of emerging cracks normal to the reinforcement that might otherwise lead to failure, mainly with brittle matrices. Man-made fibers or filaments of non-polymeric materials exhibit much greater strength along their length since large defects, which may be present in the bulk material, are decreased because of the small cross-sectional dimensions of the fiber. Orientation of the molecular structure is responsible for high strength and stiffness, in case of polymeric materials.

1.6 Lamina and Laminate

A lamina or a ply is formed by a combination of a large number of fibers in a thin layer of matrix. Fibers in the lamina may be continuous or discontinuous, arranged in a specific direction or in random orientation. A unidirectional lamina is one where the fibers in a lamina run parallel to one another in a particular direction. However, with the random orientation of fiber, it is possible to obtain nearly equal mechanical and physical in all direction in the plane of a lamina.

A laminate is formed by stacking several laminas. It is the most common form of fiber reinforced composites. It is made up of a desired thickness so as to enable it to support a given load and maintain a given deflection. Fiber orientation of each lamina and stacking sequence of various layers can be varied to obtain a wide range of physical and mechanical properties of composite.

1.7 Natural fibers reinforced composites

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their fundamental research and industrial applications. They are cheap, renewable, partially or completely recyclable and biodegradable. Plants, such as jute, cotton, flax, hemp, kenaf, sisal, ramie, pineapple, bamboo, banana, etc., as well as wood, used from ancient as a source of lignocellulosic fibers, are more and more frequently applied as the reinforcement of composites. Their low density, renewability, availability and price as well as satisfactory mechanical properties make them a pretty ecological alternative to carbon, glass and man-made fibers used for the manufacturing of composites. The natural fiber-reinforced composites are more environmental friendly, and are used in transportation (aerospace, automobiles and railway coaches,), building and construction industries (partition boards, ceiling paneling,), military applications, consumer products and packaging etc.

1.8 Application of Natural fibers reinforced composites

The natural fiber composites can be very cost effective material for following applications:

- Building and construction industry: partition boards, panels for partition and false ceiling, floor, wall, door frames, window and roof tiles, pre-fabricated buildings which can be used in times of natural calamities such as cyclones, floods, earthquakes, etc.
- Storage devices: grain storage silos, bio-gas containers, post-boxes, etc.
- Furniture: table, chair, bath units, shower, etc.
- Electric devices: pipes, electrical appliances, etc.
- Everyday applications: suitcases, helmets, lampshades, etc.
- Transportation: boat, automobile and railway coach interior, etc.

1.9 Luffa cyllindrica as a natural fiber

There are many potential natural resources, which India has in large quantity. Most of it comes from the agriculture and forest.

Fig 1.1 (a)

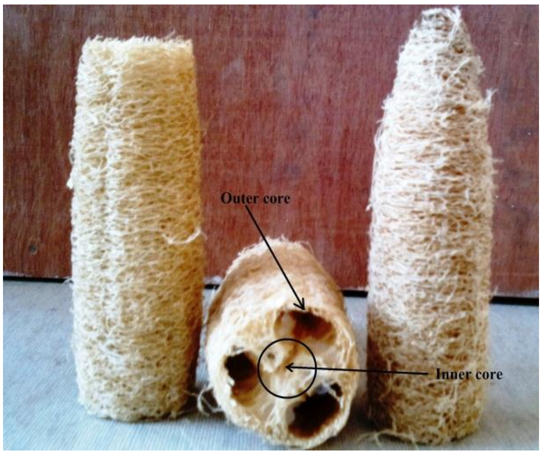

Fig 1.1 (b)

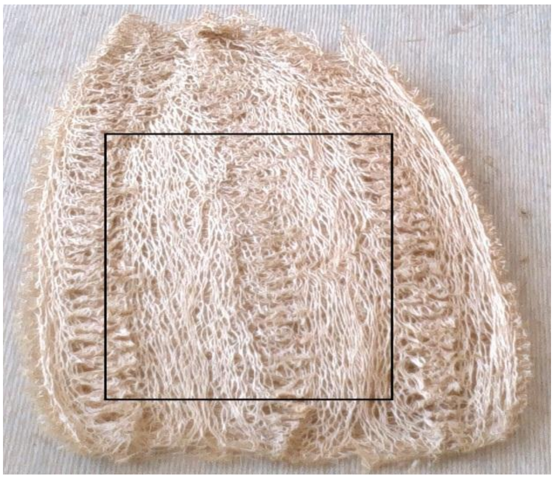

Fig 1.1 (c)

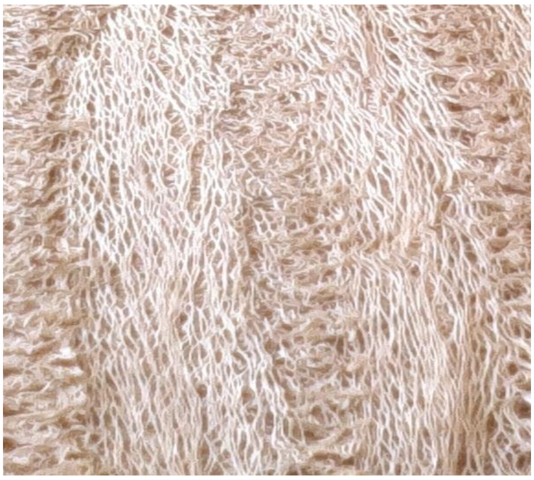

Fig 1.1 (d)

Fig. 1.1 The L. cylindrica plant with fruit (a), the inner fiber core (b) and the outer core open as a mat (c, d).

Luffa cylindrica, locally called, as 'Sponge-gourds' is one such natural resource whose potential as fiber reinforcement in polymer composite has not been explored to date. It has a ligneous netting system in which the fibrous cords are disposed in a multidirectional array forming a natural mat. This fibrous vascular system is composed of fibrils glued together with natural resinous materials of plant tissue. It contains 62% cellulose, 20% hemicellulose and 11.2% lignin [1]. The fruit of the sponge-gourd (L. cylindrica) plant with fruit which is of the Curcubitacea family is shown in Fig. 1.1(a) which has a thick peel and the sponge-gourd, which has a multidirectional array of fibers comprising a natural mat, presents an inner fiber core (Fig. 1.1(b)) and an outer matcore (Fig. 1.1(c, d)).

The main objective of this work is to prepare a PMC using luffa fiber as reinforcement and epoxy as matrix material and to study its tensile and flexural properties. Out of the available manufacturing processes, we have choose hand-lay-up technique to prepare the composite. Then the composites were manufactured by varying layers of fiber that is with single, double and triple layer fibers using these techniques.

In the second chapter work related to present investigation available in literature are presented.

The third represent the materials methods used for preparation of specimens for the composites, their characterization on mechanical testing.

In fourth chapter results of the tested samples were discussed.

In fifth conclusions have been drawn from the above studies mentioning the scope for future work.

The sixth chapter represents the references used for the research of this project work.

Chapter 2

Literature Survey

This section stresses on the research work that has already been carried out for testing the mechanical properties of the Natural Fiber Reinforced Hybrid composites. Literature review of such work needs to be done in order to understand the background information available, the work already done and also to show the significance of the current project. This chapter presents a general knowledge of the factors which affect the mechanical properties of hybrid fiber reinforced polymer composites.

Natural fiber reinforced composites have elevated abundant attentions and interests among materials experts and engineers in recent years due to the reflections of developing an environmental friendly material and partly replacing currently used carbon or glass fibers in fiber-reinforced composites. They are high specific strength and modulus materials, recyclable, low cost, easily available in certain countries, etc.

Satyanarayana *et al.* [1] have studied on lignocellulosic fibers of Brazil. They reported the availability of some of the Brazilian lignocellulosic fibers, their market, extraction methods, properties and their current applications. International trends in the study of lignocellulosic fibers tell that, these fibers have latent use in automotive applications; they can be perfect competitors for the non-renewable, costly petroleum-based synthetic fibers in composite materials, mainly in the automotive industry and counting building sectors.

Andrzej *et al.* [2] have investigated the influence of the type of reinforcing fiber, fiber and microvoid content on the mechanical properties of composites. Increasing the fiber content persuades an increase in the impact strength and shear modulus. Though, increasing the microvoid content in the matrix results in decreased impact strength and shear modulus.

Verma *et al.* [3] have discussed the usage of bagasse fiber and its current eminence of research. Many references to the latest work on properties, processing and application have been quoted in this appraisal. The objective of their study was to utilize the benefits offered by renewable resources for the development of composite materials based on bagasse fibers. They conclude that hybridization with some amounts of synthetic fibers makes these natural fabric composites more appropriate for technical applications such as automotive interior parts. The chance of surface chemical alteration of bagasse fibers have been widely used in an extensive variety of application, e.g., furniture's, packaging and electronic display materials.

Herrera-Franco *et al.* [4] have investigated the mechanical behavior of high density polyethylene (HDPE), reinforced with continuous henequen fibers (Agave fourcroydes). They found that the subsequent strength and stiffness of the composite depends on the amount of silane deposited on the fiber and the elastic modulus of the composite did not improve with the fiber surface modification. They also observed that the increase in stiffness from the use of henequen fibers was roughly 80% of the calculated values and the increase in the mechanical properties stretched between 3 and 43%, for the longitudinal flexural and tensile properties, where in the transverse direction to the fiber, the increase was more than 50% with respect to the properties of the composite prepared with untreated fiber composite. In the case of the shear strength, the increase was of the order of 50%. From the failure surfaces they found that with increasing fiber matrix interaction the failure mode altered from interfacial failure to matrix failure.

Rokbi *et al.* [5] have studied the influence of chemical treatments of fibers by alkalization on the flexural properties of Alfa fiber reinforced polyester matrix composites. They reported the influence of alkaline treatments on the flexural properties to govern the peak conditions of alkaline treatment. The experimental results demonstrate that the bending behavior of composites made from alkali treated fibers are better compared to the untreated fiber composite, For a fiber processing Alfa 10% NaOH in 24h, the flexural strength and flexural modulus improved by 23 MPa to 57MPa and from 1.16 to 3.04 GPa. Still, the flexural properties of composites decreased after alkali treatment with 5% NaOH for 48 h. This is essentially because of the decrease of lignin that binds the cellulose fibrils together.

Oboh *et al.* [6] have reported the potentialities of Luffa cylindrica crop that is virtually found around the world. Areas such as medicine, agriculture, science, biotechnology and engineering were discussed. Recent major advances and discoveries were considered. They conclude that in the context of the morphosynthesis, the ability of replication of the luffa sponge unties the chances of the use of biodiversity in obtaining new materials. This emerging cash crop will expand the economies of many nations in the nearest future because of its numerous potentials.

Yoldas Seki *et al.* [7] carried out characterization of Luffa cylindrica by Fourier transform infrared spectrophotometer, X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and thermogravimetric analysis. Hemicellulose, cellulose, and lignin contents of Luffa cylindrica were also determined. They subject luffa cylindrica-reinforced polyester composite to water aging under a steam of seawater containing 5% sodium chloride for 170 h at 50^0C. They found that flexural strength, tensile strength, tensile elongation and interlaminar shear strength at break values of the composite decreased by 28%, 24%, 45%, and 31%, respectively, after water aging. However, tensile modulus and flexural modulus did not change significantly.

Lassad Ghali *et al.* [8**]** have studied the effect of chemical modification of luffa fibers on the mechanical and hygrothermal behaviors of polyester composites. They reported that the acetylation treatment improved the mechanical properties of composites. The process decreased the hydrophilic behavior of the luffa fibers, improving their adhesion to polyester matrix. The chemical alterations at the surface of the luffa fibers also decreased the diffusion coefficient and the maximum amount of water absorbed by these fibers. The diffusion process was found to be affected by external loads applied on the exposed composite materials.

Msahli *et al.* [9] have reported the influence of fiber weight ratio ,reinforcement structure and chemical modification, on the flexural proprieties of Luffa-polyester composites. It resorts that acetylating and cyanoethylating improve the flexural strength and the flexural modulus. They found that the fiber weight ratio influenced the flexural properties of composites. Certainly, a maximum value of strength and strain is observed over a 10% fiber weight ratio. They investigated the uses of various reinforcement structures.

Demir *et al.* [10] have investigated the influence of coupling agents on the morphological, mechanical, and water sorption properties of luffa fiber reinforced composites. They establish that the Tensile strength and Young’s modulus increased with employment of the coupling agents convoyed by a decrease in water absorption with treatment because of the better adhesion between the fiber and the matrix. They obtained the maximum improvement in the mechanical properties for the MS treated LF composites. The interfacial contacts improved the mechanical properties, water resistance and filler compatibility of composites. They reported that better adhesion between the fiber and the matrix was achieved especially for the MS and AS treated LF composites. Atomic force microscope (AFM) studies also showed that the surface roughness of LFs decreased with the employment of silane-coupling agents.

A detailed review of the literature survey illustrate that the hybrid composites have a lot of potential as advanced materials in numerous diverse sectors such as automotive, structural, aerospace and marine applications. However owing to their current discovery, not much research has been done on the effects of the fiber parameters such as fiber length and fiber loading on the mechanical performance of the polymer composites. Moreover, there exist very few literatures on the effect of luffa- fiber-reinforcement on polymer composites.

Chapter 3

Materials and Methods

This chapter details the materials used and methodologies adopted during the sample preparation, fabrication, mechanical testing and characterization of the composites.

3.1 Raw Materials

Raw materials used in this experimental work are:

(i) Luffa fiber
(ii) Epoxy resin
(iii) Hardener

3.1.1 Luffa fiber

Luffa cyllindica, locally called, as ‘Sponge-gourds’ is one such natural resource whose potential as fiber reinforcement in polymer composite has not been explored to date. It has a ligneous netting system in which the fibrous cords are disposed in a multidirectional array forming a natural mat. This fibrous vascular system is composed of fibrils glued together with natural resinous materials of plant tissue. The main chemical constituents of luffa are Hemicellulose, cellulose and lignin. Cellulose and hemicellulose are present in the form of hollow cellulose in luffa which contributes to about 82 % of the total chemical constituents present in luffa. Another important chemical constituent present in luffa is lignin. Lignin acts as a binder for the cellulose fibers and also behaves as an energy storage system.

3.1.2 Epoxy resin

Epoxy resin (Araldite LY 556) having the following outstanding properties has been used.

i. Outstanding adhesion to different materials

ii. Abundant strength, toughness resistance

iii. Outstanding resistance to chemical attack and to moisture

iv. Brilliant mechanical and electrical properties.

v. Odorless, tasteless and completely nontoxic.

vi. Insignificant shrinkage.

3.1.3 Hardener

In the present work Hardener (araldite) HY 951 is used. This has a viscosity of 10-20 poise at 25^0C.

3.2 Sample Preparation

The composite fiber is prepared by hand lay-up technique:

The luffa fiber which is taken as reinforcement in this study is collected from local sources. Then it is properly cleaned and cut to appropriate size. Wooden moulds with dimensions of 140 x 70 × 5 mm^3 were prepared for composite fabrication. For different volume fraction of fibers, an calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed in a glass jar. Figure 3.1 illustrates the mould used to construct the composite. For quick and easy removal of composite, mold release sheet was put over the glass plate and a mold release spray was applied at the inner surface of the mold. After keeping the mold on a ply board a thin layer of the mixture was poured. Then the fiber lamina was distributed on the mixture. Then again resin was applied over the fiber laminate and the procedure was repeated to get the desired thickness. The remainder of the mixture was then poured into the mold. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mold was allowed to preserve at room temperature for 72 hrs. During application of pressure some amount of mixture of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing of composite sheets. After 72 hrs the samples were taken out of the mold. Figure 3.3 (a, b) shows the photograph of the composite specimen cut for further experimentation.

Fig 3.1 Mould used for fabrication of the composite

3.3 Experimental Procedure

3.3.1 Density measurement of sample:

The density of the sample is calculated by using a pycnometer by the following equation:

$$\rho = \left[\frac{(W_2 - W_1)}{\{(W_4 - W_1) - (W_3 - W_2)\}}\right] \times \text{Density of kerosene}$$

Where W_1 is the weight of the empty dry and clean pycnometer, W_2 is the weight of the pycnometer containing the sample, W_4 is the weight of the pycnometer containing the kerosene, and W_3 is the weight of the pycnometer containing the sample and kerosene.

Using the formula, the value of density was measured as 0.540 g/cc

Fig 3.2 shows the pycnometer used for density measurement of sample.

Fig-3.2 Pycnometer

3.3.2 Cutting of laminates into samples of desired dimensions

A WIRE HACKSAW blade was used to cut each laminate into smaller pieces, for various experiments:

- TENSILE TEST- Sample was cut into dog bone shape (140x10x5) mm.

- FLEXURAL TEST- Sample was cut into flat shape (15x140x5) mm, in accordance with ASTM standards.

Fig 3.3 (a) Dog bone shape sample

Fig-3.3 (b) Flat bar shape sample

3.3.3 Mechanical testing of sample

3.3.3.1 Tensile test

The tensile test is generally performed on flat specimens. The most commonly used specimen geometries are dog-bone and the straight side type with end tabs. The specimen used in present case is shown in fig 3.3 (a). The tensile tests were conducted according to ASTM D 3039-76 standard on a computerized Universal Testing Machine INSTRON H10KS. The span length of the specimen was 42 mm. the tests were performed with constant strain rate of 2 mm/min.

Fig 3.4 (a) UTM machine Sample unloaded condition for tensile testing.

Fig 3.4 (b) UTM machine Sample loaded condition for tensile testing.

3.3.3.2 Flexural test

Three point bend test was carried out in an UTM machine in accordance with ASTM D790-03 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used are shown in figure 3.5. All the specimens (composites) were of rectangular shape having length varied from 100-125 mm, breadth of 100-110 mm and thickness of 4-8 mm. A span of 70 mm was employed maintaining a cross head speed of 0.5mm/min.

The flexural strength of composites was found out using the following equation

$$\tau = \frac{3fl}{2bt^2}$$

Where τ is the flexural strength, f is the load, l is the gauge length, b is the width and t is the thickness of the specimen under test.

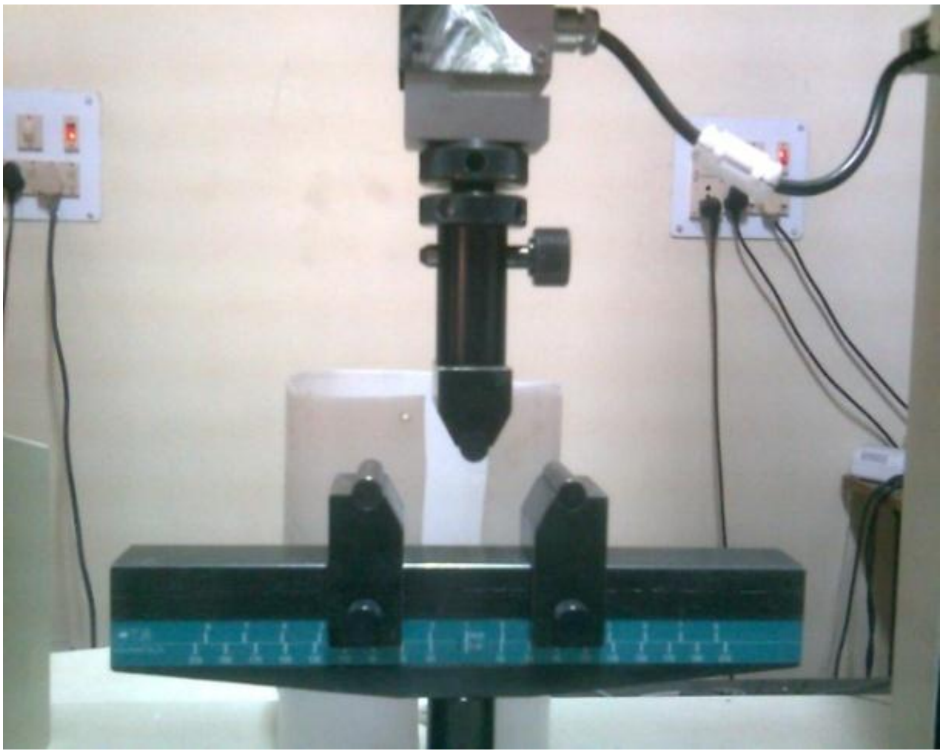

Fig 3.5 UTM machine Sample unloaded condition for Flexural testing.

Chapter 4

Results and Discussion

4.1 Tensile test

Tensile test was carried out on UTM machine in accordance with ASTM D 3039-76 standard. All the specimens were of dog bone shape of dimension (140x10x5) mm. The results single, double and triple layer samples are tabulated in the table 4.1.

Table-4.1 (tensile test data)

sample	Volume fraction of fiber(%)	Tensile strength (MPa)
S_0	0	13.5
S_1	14.06%	14.76
S_2	20.55%	16.77
S_3	31.05%	7.32

Where S_0 stands for neat epoxy sample with 0 % volume fraction of fiber, S_1 stands for single layer luffa reinforced sample with 14.06 % volume fraction of fiber, S_2 stands for double layer luffa reinforced sample with 20.55% volume fraction of fiber content, S_3 stands for triple layer luffa reinforced sample with 31.05% volume fraction of fiber content.

So by calculating the tensile strength of all samples it was found that S_2 has the highest tensile strength i.e., 16.77 MPa.

It is well known that fiber content and fiber strength are mainly responsible for strength properties of the composite. Therefore the variation in tensile strength of the single, double, and triple layer samples are presented in Table-4.1 and shown in fig 4.1 (a, b). There is gradual increase in tensile strength for single, double layer composite.

However, the decrease in tensile strength for triple layer composite (s_3) may be due to the poor fiber-matrix adhesion.

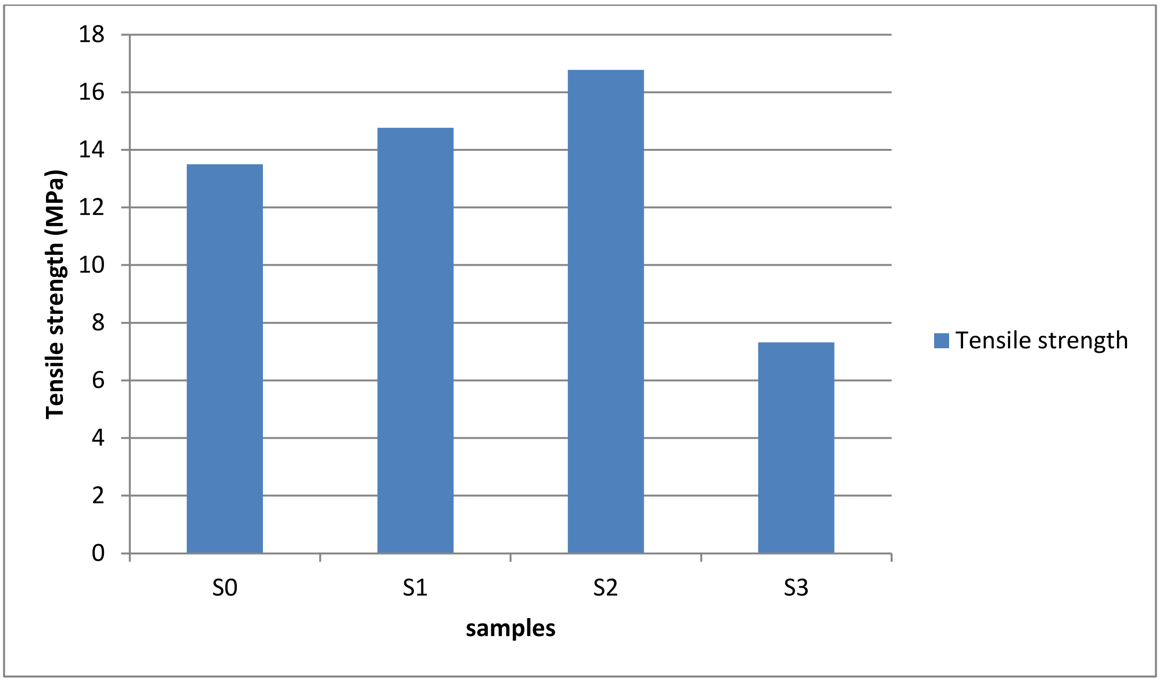

Fig 4.1 (a) Variation of Tensile strength with different layers of samples

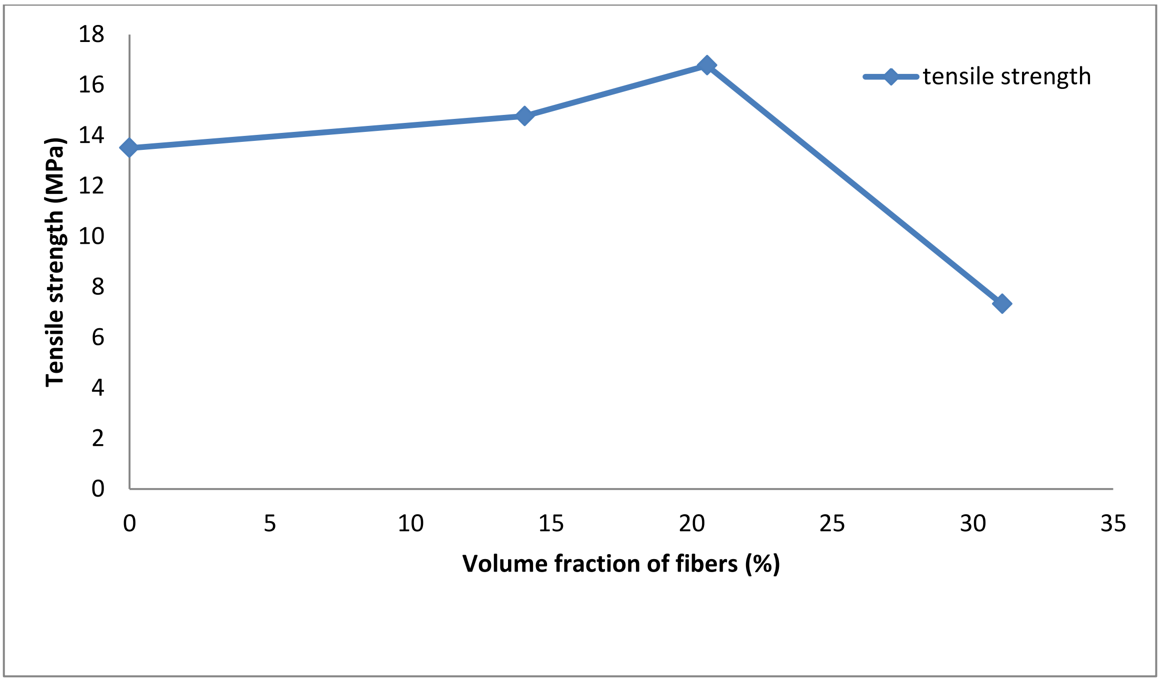

Fig 4.1 (b) Variation of Tensile strength with different volume fraction of fibers

4.2 Flexural test

Three point bend test was carried out in an UTM machine in accordance with ASTM standard to measure the flexural strength of the composites. All the specimens (composites) were of rectangular shape having dimension of (140x15x5) mm. The span length was 70mm. The experiment was conducted on all three samples of luffa fiber combinations. The results are tabulated in the Table 4.2.

Table 4.2 (flexural test data)

sample	Volume fraction of fiber(%)	Flexural strength (MPa)
S_0	0	17.6
S_1	14.06%	23.08
$\mathbf{S_2}$	**20.55%**	**24.28**
S_3	31.05%	22.15

So by calculating flexural strength for all samples it was found that S_2 has the highest value i.e., 24.28 MPa.

The variation in flexural strength of the neat epoxy, single, double, and triple layer are presented in Table-4.2 and shown in fig- 4.2 (a, b).

Poor fiber wetting occurs due to insufficient matrix material which results in lower flexural strength of the triple layer composite (s_3).

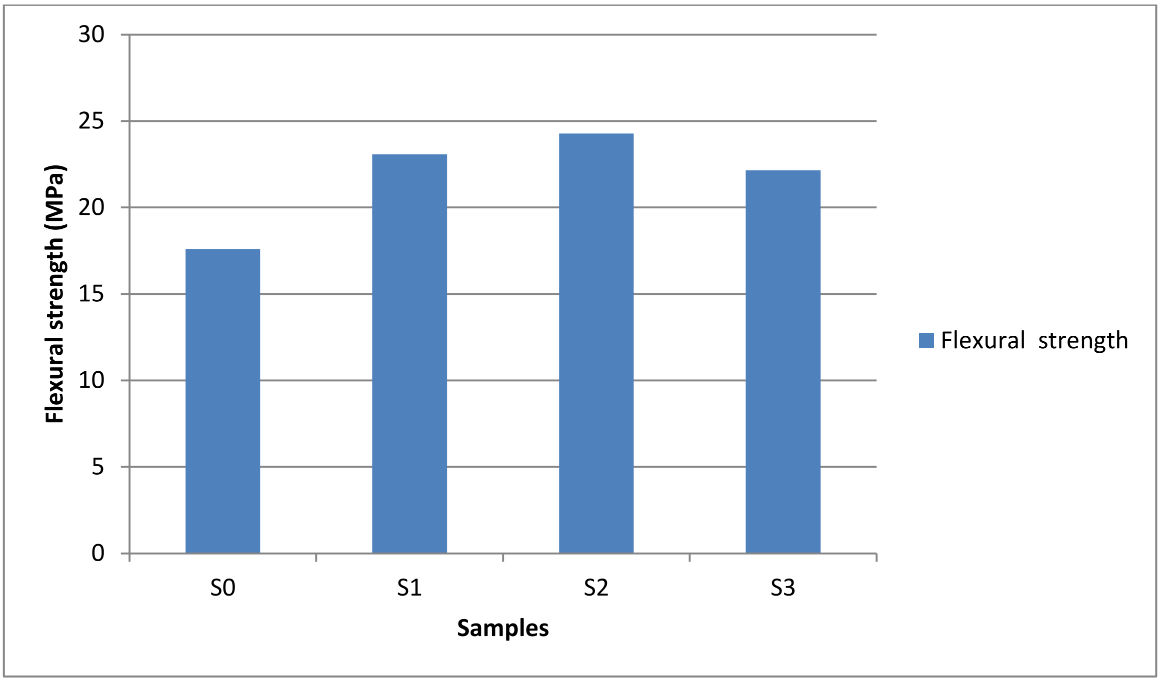

Fig 4.2(a): Variation of Flexural strength with different layers of samples

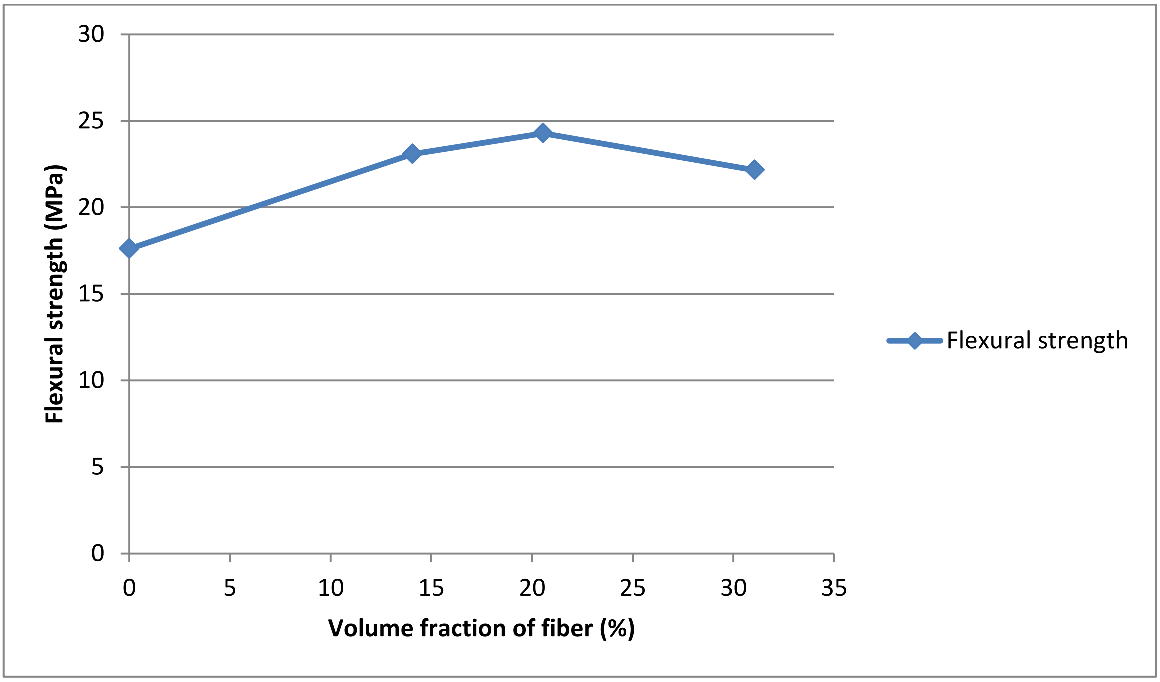

Fig 4.2(b) Variation of Flexural strength with different volume fraction of fiber

Chapter 5

Conclusions

5.1 Conclusions

The present work deals with the preparation of luffa fiber reinforced epoxy composite. The mechanical behavior of the composite lead to the following conclusions:

1. The successful fabrications of a new class of epoxy based composites reinforced with luffa cylindrica natural fibers have been done.
2. It has been observed from this work that the tensile strength is maximum for double layer ($S_{2)}$ sample i.e., 16.77 MPa which is greater than neat epoxy i.e., 13.5 MPa. However, there is an abundant decrease in tensile strength observed for triple layer composite (S_3). This decrease in strength is may be due to poor fiber-matrix adhesion.
3. However, flexural strength is found to be more than neat epoxy (S_0) for all layers of luffa fiber reinforced composites. And it is found to be maximum for double layer (S2) sample i.e., 24.28 MPa which is greater than neat epoxy i.e., 13.5 MPa. The lowest value of flexural strength is observed for triple layer (S_3) i.e., 22.15 MPa. This is may be due to insufficient matrix material compared to volume fraction of fibers which results in lower flexural strength of the triple layer composites.
4. Possible use of these composites such as in Building and construction industry (partition boards, panels for partition and false ceiling, floor, wall, window and door frames etc.), Storage devices (grain storage silos, post-boxes, bio-gas containers etc.) is recommended. However, this study can be further extended in future to new types of composites using other potential natural fibers/fillers and the resulting experimental findings can be similarly analyzed.

5.2 Scope for future work

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other tribological aspects like abrasion, wear, hardness behavior of this composite. We can also study other aspects of such composites like use of other potential fillers for development of hybrid composites and evaluation of their mechanical and erosion behavior and the resulting experimental findings can be similarly analyzed.

Chapter 6

References

1. K.G. Satyanarayana, J.L. Guimara, F. Wypych, 2007, "Studies on lignocellulosic fibers of Brazil. Part I: Source, production, morphology, properties and applications, Composites", Part A 38 (2007) 1694–1709
2. Andrzej K., Bledzki. Andris Chate., 2009, "Natural fiber-reinforced polyurethane microfoams", 61 (2001) 2405–2411
3. Verma, D., Gope, P.C., Maheshwari, M.K., Sharma, R.K., 2012, "Bagasse Fiber Composites-A Review", J. Mater. Environ. Sci. 3 (6) (2012) 1079-1092
4. Herrera-Franco, P.J., Valadez-Gonza´lez, A., 2004, "Mechanical properties of continuous natural fibre-reinforced polymer composites", Composites: Part A 35 (2004) 339–345
5. Mansour Rokbia, Hocine Osmania, Abdellatif Imadc , Noureddine Benseddiqd(2011) "Effect of Chemical treatment on Flexure Properties of Natural Fiber-reinforced Polyester Composite", Procedia Engineering 10 (2011) 2092–2097
6. Oboh I. O. Aluyor E. O., 2009, "*Luffa cylindrica* - an emerging cash crop"**,** African Journal of Agricultural Research Vol. 4 (8), pp. 684-688, August 2009
7. Yoldas Seki, Kutlay Sever, Seckin Erden, Mehmet Sarikanat, Go¨kdeniz Neser, Cicek Ozes, 2011, "Characterization of Luffa cylindrica Fibers and the Effect of Water Aging on the Mechanical Properties of Its Composite with Polyester", DOI 10.1002/app.34744
8. Lassaad Ghali, Mourad Aloui, Mondher Zidi, Hachmi Bendaly and Faouzi Saki, "effect of chemical modification of luffa cylindrica fibers on the mechanical and hygrothermal behaviours of polyester composites", bioresource.com
9. Lassaad Ghali, Slah Msahli, Mondher Zidi, Faouzi Sakli, 2011," Effects of Fiber Weight Ratio, Structure and Fiber Modification onto Flexural Properties of Luffa-Polyester Composites", *Advances in Materials Physics and Chemistry*, 2011, 1, 78-85
10. Demir H., Atikler U., Balkose D., Tihminhoglu F., 2006, "The effect of fiber surface treatment on the tensile and water sorption properties of polypropylene -luffa fiber composites", Composites: Part A 37 (2006) 447–456

11. Ghali l., Msahli s., Zidi M., Sakli F., 2009, “Effect of pre-treatment of Luffa fibers on structural properties”, Materials Letters 63 (2009) 61–63.

12. Valcineide O.A., Tanobe, Thais H.D., Sydenstricker, Marilda Munaro, sandro c. Amico.,2005, “A comprehensive characterization of chemically treated Brazilian sponge-gourds(Luffa cyllindrica)”, Polymer Testing 24 (2005) 474–482

13. Valcineide O.A. Thais H.D. Marilda Munaro, Sandro C., 2005, “Corrigendum to A comprehensive characterization of chemically treated Brazilian sponge-gourds (Luffa cylindrical)”, Polymer Testing. Volume 24 (2005) p. 474–482

14. Mukherjee, P. S. & Satyanarayana, K. G., 1986, “Structure and properties of some Vegetable fibers-II. Pineapple leaf fiber,” J. Material Science 21, pp. 51–56.

15. Verma, D., Gope, P.C., Maheshwari, M.K., Shandilya, A. , Gupta, A., 2013,” Coir Fibre Reinforcement and Application in Polymer Composites: A Review”, J. Mater. Environ. Sci. 4 (2) (2013) 263-276